

Towards the Use of POP in a Global Coupled Navy Prediction System

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Document Number: N0001402WR20127

<http://www.oc.nps.navy.mil/navypop>

LONG-TERM GOALS

Provide realistic high-resolution global ocean and ocean/ice states to Fleet Numerical Meteorological and Oceanographic Center (FNMOC) for initialization of a coupled global air/ocean/ice synoptic prediction system.

OBJECTIVES

To continue the spin up of the global eddy-resolving ocean component and evaluate its realism using observations. Perform sensitivity runs to address model weaknesses and mixed layer responses. Analyze mesoscale and frontal processes.

APPROACH

The Parallel Ocean Program (POP) model was configured on a global displaced North Pole grid whereby the North Pole is rotated into Hudson Bay, avoiding the issue of the polar singularity. The grid has an average spacing of about 11 km at the equator decreasing to about 3 km in the Arctic Ocean. At mid-latitudes this spacing is 5-7 km corresponding to about $1/15^\circ$. It has 40 vertical levels. The POP code is designed to run on multi-processor machines; here we are using 500 processors on the IBM SP3 at the Navy Oceanographic Office to spin-up the ocean model for two decades.

A blended bathymetry was created from Smith and Sandwell (1997), International Bathymetric Chart of the Arctic Ocean (IBCAO, Jakobsson et al., 2000), and British Antarctic Survey (BEDMAP)

Report Documentation Page			Form Approved OMB No. 0704-0188		
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1. REPORT DATE 30 SEP 2002	2. REPORT TYPE	3. DATES COVERED 00-00-2002 to 00-00-2002			
4. TITLE AND SUBTITLE Towards the Use of POP in a Global Coupled Navy Prediction System			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Oceanography Department, Naval Postgraduate School, Monterey, CA, 93943			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Provide realistic high-resolution global ocean and ocean/ice states to Fleet Numerical Meteorological and Oceanographic Center (FNMOC) for initialization of a coupled global air/ocean/ice synoptic prediction system.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF: a. REPORT b. ABSTRACT c. THIS PAGE unclassified unclassified unclassified			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 7	19a. NAME OF RESPONSIBLE PERSON

products. All important channels and sills were checked and modified to encourage correct flow. To produce an energetically realistic ocean state, synoptic forcing was used whenever possible during the global spin-up. The forcing was largely constructed from National Center for Environmental Prediction (NCEP) fluxes (Doney et al., 2002) for 1979-1998. Surface momentum, heat, and salt fluxes were calculated using bulk formulae (Large et al., 1997) and a combination of daily NCEP analyses, monthly Internal Satellite Cloud Climatology Project (ISCCP) radiation data, and monthly Microwave Sounding Unit (MSU) and Xie-Arkin precipitation data. Background restoring of sea surface temperature and sea surface salinity to ‘under ice’ values with a restoring time scale of 1 month is active. Elsewhere, for surface salinity only, a time scale of 6 months is used. The Large et al. (1994), mixed layer formulation, K-Profile-Parameterization, was turned on after the first year of the spin-up.

WORK COMPLETED

Fifteen years (1979-1994) of the global spin-up are complete. It is monitored in terms of its ability to reproduce the observed ocean state. The mean and variability of the simulated circulation are compared with quantities calculated from data sets with global or near-global coverage such as those obtained from satellite altimeters and drifting buoys. Root-mean-square (RMS) sea surface height (SSH) is calculated from TOPEX/POSEIDON altimetry on a near-global basis and annual surface mean flows (15 m) are calculated from drifting buoys in ocean basins with sufficient measurements. It should be noted that the data sets and model output are not concurrent, as the model integration has not progressed far enough in time to cover those periods when the data was collected. Differences are to be expected from comparing data and model fields from different time periods and of different temporal extent, but since the data is providing a guide to the first-order accuracy of the spin-up, these differences are neglected. Here we present some highlights of these analyses to demonstrate both realistic and unrealistic flows.

RMS SSH fields, in $2^\circ \times 2^\circ$ bins, from the global run during 1986 and TOPEX/POSEIDON (T/P) altimetry (1993/1994) are shown in Figure 1. These results indicate that the distribution and strength of the variability associated with strong currents are generally well reproduced. In the interior however, the variability is low, although within the limits of the altimeter measurement error. A $2^\circ \times 2^\circ$ binned annual mean field was constructed from 1986 model velocities at the second upper-most model level (15m). Figure 2a focuses on the Pacific basin from this field and can be compared with a mean velocity field (1990s) constructed from surface drifters at 15m (Figure 2b). Western boundary currents are seen to separate from the continental shelf at roughly the correct location. In particular, the Kuroshio Extension and the Tasman Front (the offshore extension of the East Australian Current) are found within one degree of the latitude of their observed locations. This is an improvement over their representation in previous lower resolution POP integrations (McClean et al., 1997; Maltrud et al., 1998) where western boundary current separations were shifted several degrees poleward of the observed positions. Further description of the model spin-up and movie loops can be seen at <http://www.oc.nps.navy.mil/navypop>.

These preliminary spin-up analyses indicate that the state of the evolving surface circulation is proceeding with a reasonable degree of realism with the exceptions of the Gulf Stream separation, the North Atlantic Current (NAC) and the Canadian Archipelago. Lack of an ice model and overly strong winds were responsible in the latter case; this was corrected by changes to the Archipelago topography to account for the lack of ice. A North Atlantic POP simulation at the same resolution as the global model, forced with the same surface fluxes but on a Mercator grid, was conducted in an attempt to

understand the roles of the forcing and the global grid. The North Atlantic POP displayed a reasonable Gulf Stream separation but a poor representation of the NAC pathway at the Northwest Corner. A group of collaborators including McClean and Maltrud, Bryan (NCAR), and Smith (LANL) are conducting a suite of horizontal diffusivity sensitivity runs using the global and North Atlantic models as computer resources become available to resolve these issues.

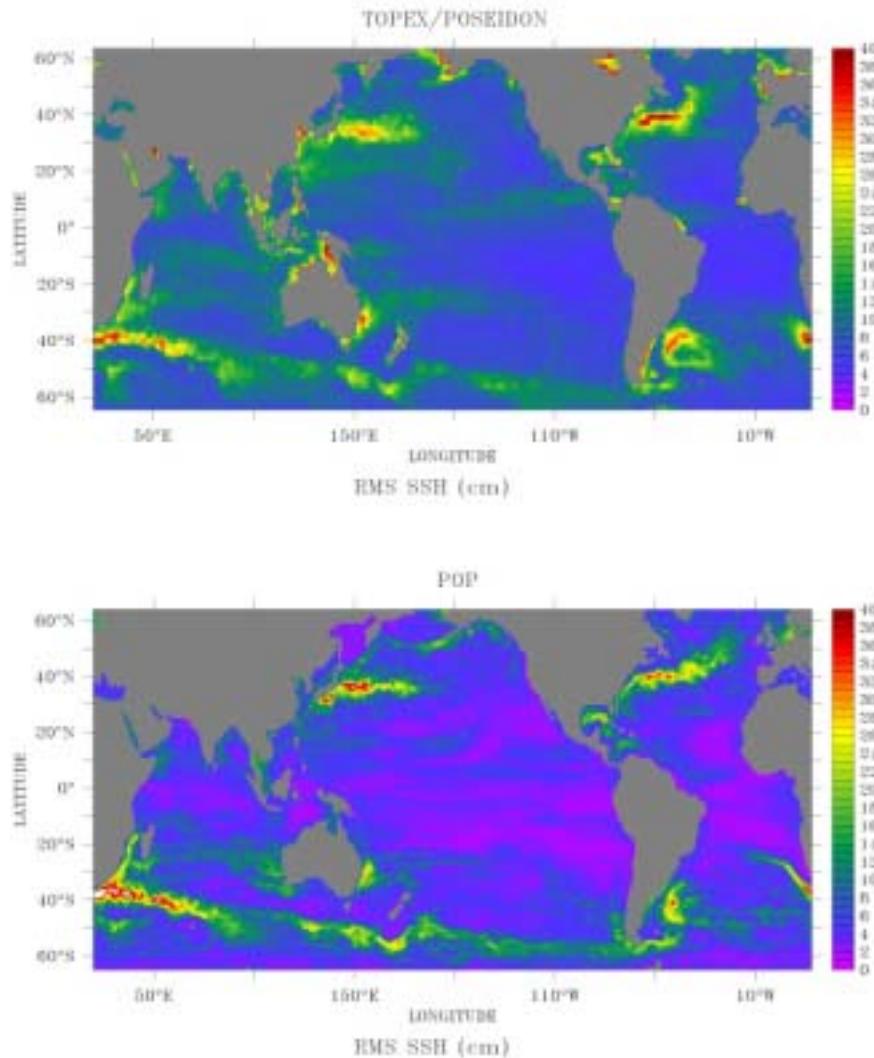


Figure 1: RMS SSH (cm) from POP (1986) and T/P (1993/994) altimetry

Sensitivity studies using an eddy-permitting global configuration of POP were conducted to study mixed layer responses. This model is the same as the eddy-resolving simulation in all respects, except for the horizontal resolution and choice of horizontal friction coefficients. In particular, the effects of penetrative solar radiation on the upper ocean thermal structure were investigated using attenuation depths derived from remotely sensed ocean color (chlorophyll data from SeaWiFS). A run with spatially and temporally varying attenuation depths was compared to that with a constant attenuation

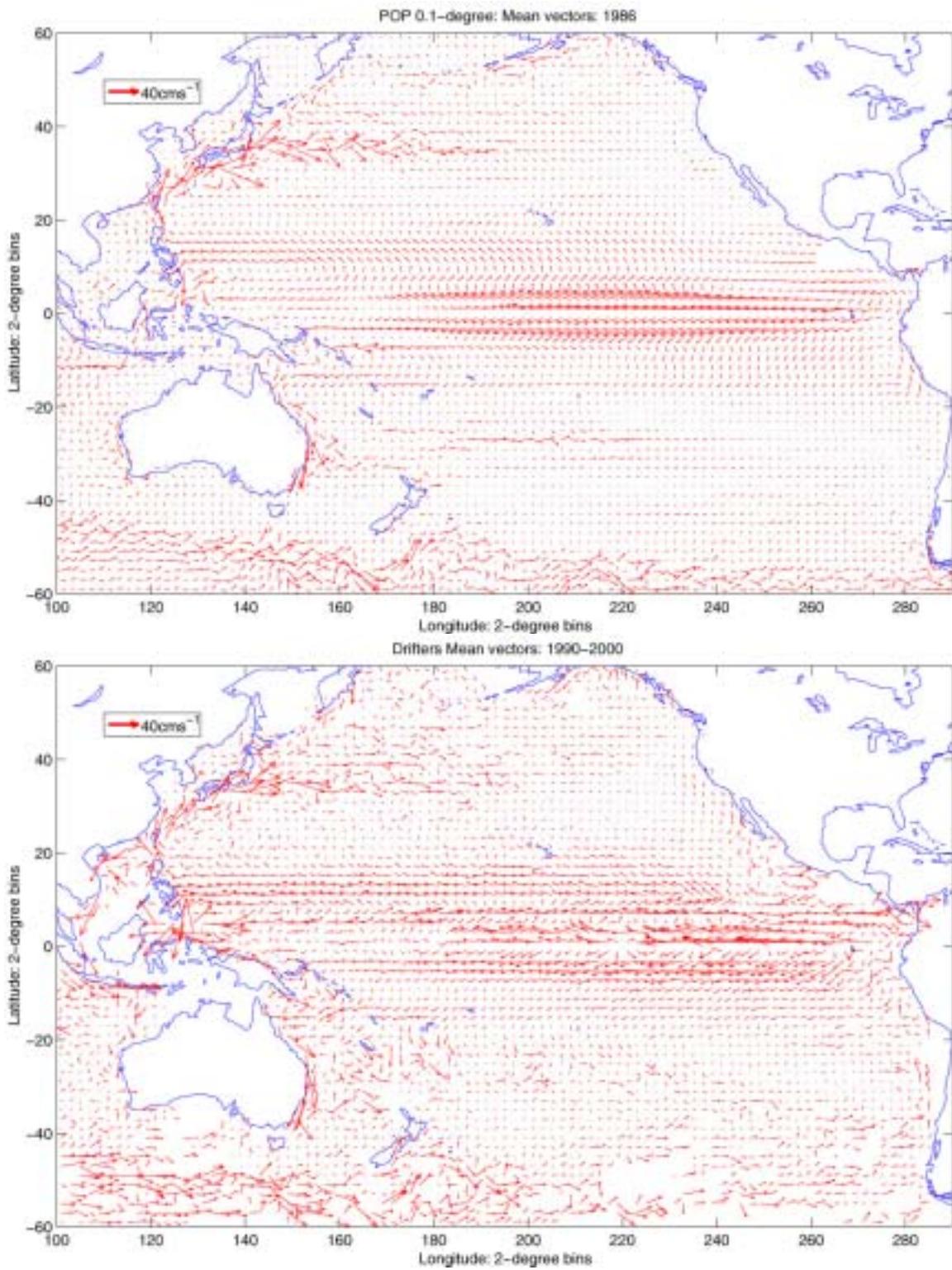


Figure 2: Annual mean (1986) model velocities from the second upper-most level (15 m) of the 0.1° , 40-level POP simulation and (b) the mean velocity field for the 1990s constructed from surface drifters at 15 m in the Pacific Ocean. Both sets of velocities are averaged into $2^\circ \times 2^\circ$ bins.

depth of 17 m (Jerlov water type = 3). The range of sea surface temperature differences was found to be -1.0-1.0°C with corresponding mixed layer depth differences of -15 to 10 m; the largest differences were found in subtropical regions. Enhanced subsurface heating (up to 0.8°C) at 97 m was also noted with variable penetration depth (Figure 3). This increased subsurface heating in turn affects the upper ocean stratification thereby increasing the mixed layer depth.

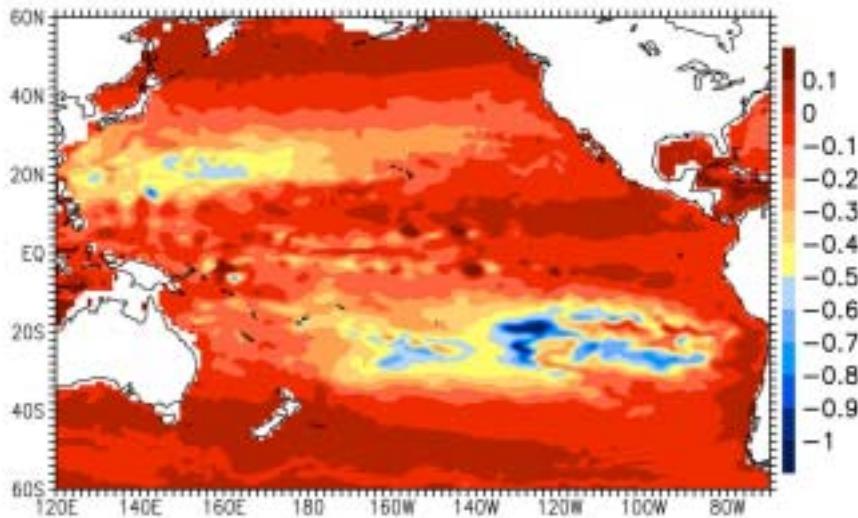


Figure 3: Differences in eddy-permitting POP subsurface temperature (°C) at 97 m between the constant attenuation depth (HP_{17}) based on Jerlov water type 3 (17 m) and seasonally varying solar attenuation depth (HP_{var}) derived from the chlorophyll (SeaWiFS) data ($HP_{17}-HP_{var}$) for the month of July 1998.

Any ocean model to be used for synoptic predictive purposes must be able to reproduce the statistical behavior of frontal and mesoscale features. The fidelity of eddy-resolving POP in this regard was examined in the Mid-Atlantic Bight during the period of the Primer Experiment. Statistical model results were compared with Primer findings and determination of the causes of the dominant model variability is underway.

IMPACT/APPLICATIONS

This spin-up will be provided to FNMOC for future operational use and to the wider community for ocean and short-term climate studies.

TRANSITIONS

The 0.1-degree, 40-level POP ocean state will be provided to FNMOC and Naval Research Laboratory (Monterey) for testing towards the operational use of POP.

RELATED PROJECTS

Mathew Maltrud (LANL) has a companion grant (N0001402IP20027) at his institution for this global POP project. NRL (Monterey) is assembling a lower resolution coupled air/ocean/ice predictive system using POP as the ocean component; they plan to use higher resolution in subsequent years.

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